Traumatic pericarditis in cattle: clinical, radiographic and ultrasonographic findings

Braun, Ueli

Abstract: Pericarditis is an inflammation of the pericardium with accumulation of serous or fibrinous inflammatory products. In cattle, it is almost always attributable to a reticular foreign body that has penetrated the reticular wall, diaphragm and pericardial sac. The lead signs of pericarditis are tachycardia, muffled heart sounds, asynchronous abnormal heart sounds, distension of the jugular veins and submandibular, brisket and ventral abdominal oedema. The glutaraldehyde test is an important diagnostic tool because it is positive in >90% of affected cattle. Other common laboratory findings are leukocytosis and hyperfibrinogenaemia (indicating inflammation), and elevation of liver enzyme activity (reflecting hepatic congestion). Radiographs of the thorax and reticulum often show a foreign body cranial to the reticulum. In the majority of cases, massive fibrinopurulent adhesions obscure the cardiophrenic angle, cardiac silhouette and ventral diaphragm. Ultrasonography is the method of choice for diagnosis and characterisation of pericardial effusion. Echogenic deposits and strands of fibrin are seen on the epicardium, and the ventricles are compressed by the effusion. Severe pleural effusion is usually evident. In cattle with distension of the jugular veins and tachycardia, the differential diagnosis includes right-sided cardiac insufficiency attributable to other causes. Distension of the jugular veins without signs of right-sided cardiac insufficiency may occur with obstruction or compression of the cranial vena cava. The prognosis is poor, and pericardiocentesis or pericardiotomy are inadequate methods of treatment. Thus, prompt and humane euthanasia is indicated for cattle with traumatic reticuloperitonitis. Because a definitive diagnosis of traumatic reticuloperitonitis is not always possible based on clinical signs alone, radiography and ultrasonography of the thorax and reticulum are indicated in doubtful cases.

DOI: https://doi.org/10.1016/j.tvjl.2008.06.021

TRAUMATIC PERICARDITIS IN CATTLE: CLINICAL, RADIOGRAPHIC AND ULTRASONOGRAPHIC FINDINGS

U. Braun [a, *]

[a] Department of Farm Animals, University of Zurich, Winterthurerstrasse 260, CH-8057 Zurich, Switzerland

* Corresponding author: Tel. +41-1-6358241; fax +41-1-6358904

E-mail address: ubraun@vetclinics.uzh.ch

Summary

Pericarditis is inflammation of the pericardium with accumulation of serous or fibrinous inflammatory products. In cattle, it is almost always attributable to a reticular foreign body that has penetrated the reticular wall, diaphragm and pericardial sac. The lead signs of pericarditis are tachycardia, muffled heart sounds, asynchronous abnormal heart sounds, distension of the jugular veins and submandibular, brisket and ventral abdominal oedema. The glutaraldehyde test is an important diagnostic tool because it is positive in more than 90 per cent of affected cattle. Other common laboratory findings are leukocytosis and hyperfibrinogenaemia, which indicate inflammation, and elevation of liver enzyme activity, which reflects hepatic congestion. Radiographs of the thorax and reticulum often show a foreign body cranial to the reticulum. In the majority of cases, massive fibrinopurulent adhesions obscure the cardiophrenic angle, cardiac silhouette and ventral diaphragm. Ultrasonography is the method of choice for diagnosis and characterisation of pericardial effusion. Echogenic deposits and strands of fibrin are seen on the epicardium, and the ventricles are compressed by the effusion. Severe pleural effusion is usually evident. In cattle with distension of the jugular veins and tachycardia, the differential diagnosis includes right-sided cardiac insufficiency attributable to other causes. Distension of the jugular veins without signs of right-sided cardiac insufficiency may occur with obstruction or compression of the cranial vena cava. The prognosis is poor, and pericardiocentesis or pericardiotomy are inadequate methods of treatment. Thus, prompt and humane euthanasia is indicated for cattle with traumatic reticuloperitonitis. Because a definitive diagnosis of traumatic reticuloperitonitis is not always possible based on clinical signs alone, radiography and ultrasonography of the thorax and reticulum are indicated in doubtful cases.

Etiology

Pericarditis is inflammation of the pericardium with accumulation of serous or fibrinous inflammatory products (Gründer 2002). It is associated with progressive disturbances in heart function and almost always results in death. In cattle, pericarditis is usually caused by long, thin sharp foreign bodies (wire, needles, nails) that penetrate the reticulum, diaphragm and pericardial sac (Fig 1) resulting in traumatic pericarditis (Fig 2). Pericarditis attributable to haematogenous spread of infectious diseases, such as colibacillosis, pasteurellosis, salmonellosis and anaerobic infections, is

much less common (Gründer 2002) and usually masked by signs of septicaemia (Gründer 2002). Idiopathic pericarditis, which is seen in humans, dogs and horses, is rare in cattle (Jesty et al. 2005).

Clinical signs

The clinical signs of traumatic pericarditis are described in detail in standard textbooks (Gründer 2002, Radostits et al. 2007) and in numerous recent case reports (Sojka et al. 1990, Ducharme et al. 1992, Moeller 1997, Grisneaux und Fecteau 2001, Schweizer et al. 2003, Jesty et al. 2005, Laureyns et al. 2005). Braun et al. (2007a) described 28 cattle with pericarditis. The lead clinical sign in affected cattle is tachycardia. Sometimes the heart rate is only mildly elevated at 80 to 100 bpm; typically, however, the heart rate is severely increased with rates as high as 130 bpm (Fig 3; Table 1). The severity of tachycardia depends primarily on the degree of compression of the heart by pericardial effusion; in cows with idiopathic pericarditis, pericardiocentesis with removal of the fluid resulted in an immediate decrease in heart rate and cure (Jesty et al. 2005). The heart sounds are muffled because of pericardial effusion and fibrinous changes in the pericardial sac; asynchronous abnormal heart sounds are characteristically present. These abnormal sounds depend on the type of lesions (Gründer 2002). With predominantly fibrinous changes, the sounds heard are of a rubbing, squeaking or scratching nature. With a predominance of fluid, there are splashing or gurgling sounds, which vary continuously in pitch, loudness, duration and point of maximal intensity. There is a varying degree of distension of the jugular veins depending on the degree of cardiac tamponade (Jesty et al. 2005, Braun et al. 2007a, Fig 4), and oedema of the submandibular region, brisket and ventral abdomen (Fig 5). Sometimes cattle stand with their elbows abducted in an attempt to facilitate cardiac function. Elbow abduction may also result from pain. Oedema and jugular vein distension may not be present if pericardial fluid drains into the reticulum via a patent foreign body tract (Gründer 2002).

The general demeanour, condition and appetite of cattle with traumatic pericarditis are always abnormal. Cattle often have signs of pain, such as bruxism and grunting, and the majority have a fever of up to 40.2 °C (Fig 6). Absence of fever does not rule out traumatic pericarditis because in rare cases the rectal temperature is normal or below normal. The respiratory rate is often elevated because of cardiac insufficiency or direct involvement of the lungs and ruminal motility is usually reduced or absent. Because pericarditis commonly results from traumatic reticuloperitonitis, tests for reticular foreign bodies are positive in 85 % of the diseased cows (Braun et al. 2007a).

Haematological and biochemical findings

The glutaraldehyde test, a nonspecific indicator of inflammation due to elevation of fibrinogen and globulin, is an important diagnostic tool because the clotting time is shorter than normal in more than 90 per cent of cattle (Braun et al. 2007a). This test can be used to differentiate inflammatory and non-inflammatory right-sided cardiac insufficiency. Leukocytosis and hyperfibrinogenaemia are also common findings and are indicative of inflammation (Fig 7). The activities of γ-glutamyltransferase (γ-GT) and aspartate aminotransferase (ASAT) and the serum concentration of bilirubin are increased, indicating hepatic congestion (Fig 8-10). It is important to remember that an increase in the activities of liver enzymes, especially γ-GT, in cattle with right-sided cardiac insufficiency is usually a sign of liver congestion and not primary liver disease. In this author's experience, cattle with right-sided cardiac insufficiency are often misdiagnosed with liver disease because of elevated liver enzyme activities or because distension of the jugular veins was missed on clinical examination or misinterpreted. This serves to emphasize how important the clinical examination is to correctly interpret the laboratory findings. In a recent study, it could be demonstrated, that the cardiac troponin proteins, which are usually present in blood either at very low concentrations or below the limit of detection of most assays, are released into the circulation in cows with pericarditis (Mellanby et al. 2007). Four of the five cases of pericarditis had a higher serum troponin concentration than any of the 34 control animals. It is important to acknowledge that this preliminary study does not demonstrate that the measurement of troponin is a specific and sensitive diagnostic test for the diagnosis of pericarditis in cattle; it merely demonstrates that cattle with pericardial disease have a higher serum troponin concentration than healthy cattle. From studies in other species, it is well recognised that serum troponin concentrations can be elevated in patients with non-primary cardiac disorders (Khan et al. 1999, Schober et al. 1999). In cattle, cardiac troponin determination may be of value in determining the degree of heart damage in cows with traumatic reticuloperitonitis (Gunes et al. 2008).

Examination of pericardial fluid

A sample of pericardial fluid may be aspirated from the pericardial sac (Radostits et al. 2007). Usually the smell, reminiscent of retained placenta and toxic metritis, is sufficiently diagnostic in cattle with traumatic pericarditis (Radostits et al. 2007). The fluid represents an inflammatory response and may be submitted for bacteriological examination. The technique is not without danger, as infection may spread to the pleural cavity.

Radiography

There are relatively few studies on radiography in cattle with traumatic reticuloperitonitis (Nigam et al. 1980, Sojka et al. 1990, Misk und Semieka 2001, Schweizer et al. 2003, Braun et al. 2007b). Laterolateral radiographic views are taken of the caudoventral thorax and reticulum with the animal standing (Braun et al. 1993, 2003). Traumatic pericarditis is diagnosed when a foreign body is seen perforating the cranial reticular wall and diaphragm, or is situated entirely cranial to the reticular wall (Fig 11-14; Table 2). For accurate localisation of a foreign body, a dorsoventral radiographic view would also be required; however, in adult cattle this is not possible because of the dorsoventral depth of the thorax. In 71 % of patients, the cardiophrenic angle was obscured and the cardiac silhouette and ventral diaphragm completely obliterated from view because of extensive fibrinopurulent lesions (Braun et al. 2007b). Gas formation is commonly seen in the caudoventral thorax and is thought to indicate bacterial infection. A gas-fluid interface is characteristic of abscess formation. Radiodense foreign bodies are usually pieces of wire or nails, although other metallic foreign bodies are sometimes seen. Traumatic pericarditis cannot be ruled out if a foreign body is not seen. Thick radiodense adhesions may obscure a foreign body from view or the foreign body may have migrated back into the reticulum, where it is seen lying freely in the organ or penetrating the reticular wall. Occasionally the offending foreign body attaches to a magnet administered after the damage has occurred. The radiographic findings must always be interpreted in relation to the clinical findings. If the radiograph shows a foreign body attached to a magnet and typical clinical signs are present, a causal relationship may be assumed and a diagnosis of traumatic reticuloperitonitis made.

Ultrasonography

Ultrasonography is the method of choice for imaging and characterising pericardial effusion. Ultrasonographic examination of the normal bovine heart was described by Braun et al. (2001). It is performed on standing cows using a 5.0 MHz linear or convex transducer from the third to fifth intercostal spaces in the cardiac region on both sides of the thorax. The ultrasonographic appearance of traumatic pericarditis has been described in a few case reports (Moeller 1997, Schweizer et al. 2003) and in a study of 22 cows (Braun et al. 2008). In most cases, a large amount of hypoechogenic fluid is seen in the thorax, sometimes containing strands or free clots of fibrin. The lungs are compressed and displaced medially and dorsally (Fig 15) by the pleural effusion. Sometimes the heart is obscured by the effusion. Affected cattle usually have a large amount of hypoechogenic to echogenic pericardial fluid, and echogenic deposits and strands of fibrin may be seen on the epicardium (Fig 16). Sometimes strands of fibrin are seen floating in the fluid between the epicardium and pericardium. Abscesses are rarely seen within the pericardial sac (Fig 17). The cardiac ventricles are moderately to severely compressed depending on the amount of fluid.

Ultrasonography of the abdomen usually reveals reticular changes typical of traumatic reticuloperitonitis, such as reduced motility and echogenic deposits. Frequently there is moderate to severe ascites attributable to cardiac insufficiency. The liver is often markedly enlarged due to congestion, and the caudal vena cava dilated so that it appears round to oval instead of triangular in cross section (Braun et al. 2002).

Differential diagnosis

Although the signs of traumatic pericarditis are usually dramatic, diagnosis is not always straightforward; some cattle do not have all of the typical signs, and other diseases have similar signs. In cattle with distension of the jugular veins and tachycardia, right-sided heart failure attributable to valvular endocarditis, cardiomyopathy, cardiac leucosis or other causes, must be considered (Gründer 2002). Distension of the jugular veins without signs of right-sided cardiac insufficiency may be caused by obstruction or compression of the cranial vena cava by a thrombus or thoracic mass. Pleural effusion has a variety of causes other than heart disease (Radostits et al. 2007).

Treatment

Various case reports have described few cattle with a positive outcome and a long term survival (Krishnamurty et al. 1979, Ducharme et al. 1992, Grisneaux and Fecteau 2001). Three therapeutic options are classically described in cases of traumatic pericarditis. A case series describing pericardiocentesis and pericardial lavage as a therapeutic option have been proved to be ineffective (Sobti et al. 1989 two of 12 described cases). The pericardiotomy associated with pericardial lavage, then closure of the pericardium with a passive drain in the pericardial cavity has also been described (Sobti et al. 1989 six cases, Gavali et al. 2003 six cases). Of those cases there were no survivors, the short term prognosis can therefore be considered as poor. Pericardiostomy with 5th rib resection has been mentioned as a therapeutic option in different case series or case reports (Ducharme et al. 1992 seven cases, Grisneaux and Fecteau 2001 one case, Gavali et al. 2003 four 4 cases). In the study of Ducharme et al. (1992) three cows died because of anesthetic complications during treatment under general anesthesia and one cow survived . The cow reported by Grisneaux and Fecteau (2001) had a normal productive life and was culled 6 years after the pericardiostomy. In the study of Gavali et al. (2003) one of the 4 cows treated by pericardiostomy had calved normally and was normal 3 months later. Based on these poor results, under normal circumstances, cattle with traumatic pericarditis should be humanely euthanased as quickly as possible. A treatment can be attempted only in a high valuable animal or in an animal carrying a high valuable embryo. The owner has to be involved in the decision of daily pericardial lavage until 2nd intention wound closure. The long term antimicrobial administration can be a problem in milking cows with prolonged withdrawal times. Therefore treatment is not cost effective in commercial cows.

Prognosis

In contrast to horses and dogs, in which pericarditis is usually attributable to disorders that often can be successfully treated (Reef 1998, Kienle und Thomas 2002), cattle almost always have a poor prognosis. In cattle, pericardial effusion is usually fibrinopurulent, whereas in horses and dogs it is often serous, serofibrinous or sanguinous and rarely has extensive fibrin production. The prognosis is still poor with pericardiocentesis or pericardiotomy. But the prognosis with pericardiostomy is slightly better (guarded to poor). The described cattle had normal milk production after the surgical treatment with pericardiostomy and left 5th rib resection (Ducharme et al. 1992, Grisneaux and Fecteau 2001) or pericardiotomy and pericardial lavage (Krishnamurty et al. 1979). Constrictive pericarditis is one of the late complications of pericarditis with fibrosis of the pericardium and fibrin (Nigam and Manohar 1973) as mentioned in humans (Braunwald 1998).

Postmortem findings

Traumatic pericarditis is characterised by fibrinopurulent changes in the pericardium and epicardium, sometimes associated with abscessation (Table 3, Fig 2, 18) as described by Roth and King (1991). The causative foreign body can usually be found (Table 4), provided that it has not been previously removed via a ruminotomy (Braun et al. 2007a). Extensive adhesions sometimes prevent retrieval of the foreign body even though it has been seen on radiographs (Braun et al. 2007a). Occasionally a diagnosis of traumatic pericarditis is based on characteristic lesions alone when no foreign body can be found on radiographs or at post-mortem examination.

Conclusion

The findings of the clinical examination alone do not always allow a definitive diagnosis of traumatic pericarditis, because all of the typical signs, which include tachycardia, muffled heart sounds, pericardial sounds, distension of the jugular veins and oedema, may not be present in every case. In doubtful cases, radiography and ultrasonography of the heart and reticulum are indicated. Radiography detects metallic foreign bodies and their location within the abdomen or thorax. With ultrasonography, effusion in the thorax, pericardium and abdomen can be detected and characterised.

References

Braun, U., Flückiger, M., Nägeli, F. (1993). Radiography as an aid in the diagnosis of traumatic reticuloperitonitis in cattle. Veterinary Record 132, 103-109.

BRAUN, U., SCHWEIZER, T., PUSTERLA, N. (2001). Echocardiography of the normal bovine heart: technique and ultrasonographic appearance. Veterinary Record 148, 47-51.

Braun, U., Flückiger, M., Feige, K., Pospischil, A. (2002). Diagnosis by ultrasonography of congestion of the caudal vena cava secondary to thrombosis in 12 cows. Veterinary Record 150, 209-213.

265 Braun, U., Lejeune, B., Schweizer, G., Puorger, M., Ehrensperger, F. (2007a). Clinical findings in 28
266 cattle with traumatic pericarditis. Veterinary Record 161, 558-563.
267 Braun, U., Lejeune, B., Schweizer, G., Feller, B., Flückiger, M. (2007b). Radiologische Befunde bei
268 28 Rindern mit Pericarditis traumatica. Schweizer Archiv für Tierheilkunde 149, 563-565.
269 Braun, U., Lejeune, B., Rauch, S., Gorber, U., Schweizer, G. (2008). Sonographische Befunde bei 22
270 Rindern mit Pericarditis traumatica. Schweizer Archiv für Tierheilkunde 149, in press.
271 Braunwald, E. (1998) Chronic constrictive pericarditis. In Harrisons's Principles of Internal
272 Medicine. 14th edn. Eds. A. S. Fauci, E. Braunwald, K. J. Isselbacher, J. D. Wilson, J. B. Martin,
273 D. L. Kasper, S. L. Hauser, D. L. Longo. McGraw-Hill, New York, pp 1339-1340.
274 Buczinski, S., Bélanger, A. M. (2004). Conduite à tenir face à une péricardite chez un bovin. Le Point
275 Vétérinaire 35, 36-39.
276 Ducharme, N. G., Fubini, S. L., Rebhun, W. C., Beck, K. A. (1992). Thoracotomy in adult dairy
277 cattle – 14 cases (1979-1991). Journal of the American Veterinary Medical Association 200, 86-
278 90.
279 Gavali, M. B., Aher, V. D., Bhikane, A. U. (2003). Surgical management of traumatic pericarditis in
280 bovine – A clinical study. Indian Veterinary Journal 80, 556-559.
281 Grisneaux, M. S., Fecteau, G. (2001). Péricardiostomie chez une holstein de deux ans 1/2. Le Point
282 Vétérinaire 32, 68-72.
283 Gründer, H. D. (2002). Krankheiten des Herzens und des Herzbeutels. In Innere Medizin und
284 Chirurgie des Rindes. 4th edn. Eds. G. Dirksen, H. D. Gründer, M. Stöber. Parey Buchverlag,
285 Berlin, pp 159-181.
286 Gunes, V., Atalan, G., Citil, M., Erdogan, H. M. (2008). Use of cardiac troponin kits for the
287 qualitative determination of myocardial cell damage due to traumatic reticuloperitonitis in cattle
288 Veterinary Record 162, 514-517.
289 Jesty, S. A., Sweeney, R. W., Dolente, B. A., Reef, V. B. (2005). Idiopathic pericarditis and cardiac
290 tamponade in two cows. Journal of the American Veterinary Medical Association 226**,** 1555-
291 1558.
292 Khan, I. A., Tun, A., Wattanasuwan, N., Win, M. T., Hla, T. A., Hussain, A., Vasavada, B. C.,
293 Sacchi, T. J. (1999). Evaluation of serum cardiac troponin I in noncardiac and cardiac diseases
294 other than acute coronary syndromes. American Journal of Emergency Medicine 17, 225-229.
295 Kienle, R. D., Thomas, W. P. (2002). Pericardial disease and neoplasia. In Small Animal Diagnostic
296 Ultrasound. Eds T. G. Nyland, J. S. Mattoon. 2nd edn. Philadelphia, W. B. Saunders. pp 412-
297 414.

298 Krishnamurty, D., Nigam, J. M., Peshin, P. K., Kharole, M. U. (1979). Thoracopericardiotomy and
299 pericardiectomy in cattle. Journal of the American Veterinary Medical Association 175, 714-718.
300 Laureyns, J., De Vliegher, S., Kolkman, I., Vandaele, L., De Kruif, A. (2005). Traumatic pericarditis
301 with “steel band-effect” sounds in a young heifer. Vlaams Diergeneeskundig Tijdschrift 74, 146-
302 148.
303 Mason, T. A. (1979). Suppurative pericarditis treated by pericardiotomy in a cow. Veterinary Record
304 105, 350-351.
305 Mellanby, R. J., Henry, J. P., Cash, R., Ricketts, S. W., Dias Bexiga, J. R., Mellor, D. J. (2007).
306 Serum cardiac troponin I concentrations in cattle with pericarditis. Veterinary Record 161, 454-
307 455.
308 Misk, N. A., Semieka, M. A. (2001). The radiographic appearance of reticular diaphragmatic
309 herniation and traumatic pericarditis in buffaloes and cattle. Veterinary Radiology & Ultrasound
310 42, 426-430.
311 Moeller, T. (1997). Klinische und sonographische Befunde bei einer Kuh mit Herzbeutelentzündung
312 und Bauchwassersucht - Fallbericht. Praktischer Tierarzt 78, 403-405.
313 Nigam, J. M., Manohar, M. (1973) Pericardectomy as treatment for constrictive pericarditis in a cow.
314 Veterinary Record 92, 202-203.
315 Nigam, J. M., Singh, A. P., Mirakhur, K. K. (1980). Radiographic diagnosis of bovine thoracic
316 disorders. Modern Veterinary Practice 61, 1021-1025.
317 Radostits, O. M., Gay, C. C., Hinchcliff, K. W., Constable, P. D. (2007). Diseases of the
318 pericardium. In Veterinary Medicine. A Textbook of the Diseases of Cattle, Horses, Sheep, Pigs,
319 and Goats. 10th edn. Philadelphia, Saunders Elsevier. pp 430-432.
320 Reef, V. B. (1998). Pericardial disease. In Equine Diagnostic Ultrasound. Ed. V. B. Reef.
321 Philadelphia, W. B. Saunders. pp 254-257.
322 Roth, L., King, J. M. (1991). Traumatic reticulitis in cattle: A review of 60 fatal cases. Journal of
323 Veterinary Diagnostic Investigation 3, 52-54.
324 Schober, K. E., Kirbach, B., Oechtering, G. (1999). Noninvasive assessment of myocardial cell injury
325 in dogs with suspected cardiac contusion. Journal of Veterinary Cardiology 1, 17-24.
326 Schweizer, T., Sydler, T., Braun, U. (2003). Kardiomyopathie, Endokarditis valvularis thromboticans
327 und Perikarditis traumatica beim Rind – Klinische und echokardiographische Befunde an drei
328 Fallberichten. Schweizer Archiv für Tierheilkunde 145, 425-430.
329 Sobti, V. K., Singh, K., Sharma, S. N., Bansal, P. S., Mattu, J. S., Rathor, S. S. (1989). Prospects of
330 surgical management of purulent pericarditis in bovines – An analysis of 12 clinical cases. Indian
331 Veterinary Journal 66, 974-977.

Sojka, J. E., White, M. R., Widmer, W. R., VanAlstine, W. G. (1990). An unusual case of traumatic pericarditis in a cow. Journal of Veterinary Diagnostic Investigation 2, 139-142.

Legend to Figures

Figure 1 : The heart and pericardial sac of a cow with traumatic pericarditis. The pericardial sac has been opened and the heart is covered with yellow fibrin. The lesions were caused by a piece of wire that perforates the diaphragm and the pericardium. (Reproduced from Braun *et al.*, 2007a).

Figure 2 : The heart and pericardial sac of a cow with traumatic pericarditis. The pericardial sac has been opened and the heart is covered with yellow fibrin. (Reproduced from Braun *et al.*, 2007a).

Figure 3 : The frequency distribution of the heart rate in 28 cattle with traumatic pericarditis. The yellow shaded area represents the normal range (60 to 80 bpm). (Reproduced from Braun *et al.*, 2007a).

Figure 4 : Oedema of the submandibular region and brisket and distension of the jugular veins in a Holstein-Friesian cow with traumatic pericarditis. (Reproduced from Braun *et al.*, 2007a).

Figure 5 : Abnormal general condition, oedema of the submandibular region and brisket and distension of the jugular veins in a Simmental cow with traumatic pericarditis. (Reproduced from Braun *et al.*, 2007a).

Figure 6 : The frequency distribution of the rectal temperature in 28 cattle with traumatic pericarditis. The yellow shaded area represents the normal range (38.5 to 39.0 ºC). (Reproduced from Braun *et al.*, 2007a).

Figure 7 : The frequency distribution of the total leucocyte count in 28 cattle with traumatic reticuloperitonitis. The yellow shaded area represents the normal range (4,000 to 10,000 leucocytes/µl). (Reproduced from Braun *et al.*, 2007a).

Figure 8 : The frequency distribution of the activity of γ-glutamyl transferase (γ-GT) in 28 cattle with traumatic pericarditis. The yellow shaded area represents the normal range (7 to 20 U/litre). (Reproduced from Braun *et al.*, 2007a).

Figure 9 : The frequency distribution of the activity of aspartate-aminotransferase (ASAT) in 26 cattle with traumatic pericarditis. The yellow shaded area represents the normal range (1 to 80 U/litre).

Figure 10 : The frequency distribution of the concentration of bilirubin in 27 cattle with traumatic pericarditis. The yellow shaded area represents the normal range (1 to 8.5 µmol/litre).

Figure 11 : Laterolateral radiograph taken at the level of the diaphragm in a cow with traumatic pericarditis. Two attached magnets are seen on the ventral surface of the reticulum. A long nail with the pointed end pointing dorsally is seen cranial to the wall of the reticulum. A number of gas shadows are visible cranial to the nail. The diaphragm is unclear because of soft tissue density between the reticulum and diaphragm. (Reproduced from Braun *et al.*, 2007b).

Figure 12 : Laterolateral radiograph taken at the level of the diaphragm in a cow with traumatic pericarditis. A linear foreign body directed craniodorsally has perforated the reticular wall and is partially outside of the reticulum. The contour of the diaphragm is unclear. Gas shadows are seen near the foreign body. (Reproduced from Braun *et al.*, 2007b).

Figure 13 : Laterolateral radiograph of the reticulum of a cow with traumatic pericarditis. The reticulum is displaced from the ventral abdominal wall, and a linear foreign body is seen cranial to the reticulum. Gas shadows and a horizontal fluid interface are seen at the ventral end of the foreign body. The lung and diaphragm cannot be differentiated because of soft tissue density. (Reproduced from Braun *et al.*, 2007b).

Figure 14 : Laterolateral radiograph taken at the level of the diaphragm in a cow with traumatic pericarditis. The reticulum contains a magnet and nail, which is vertical, not attached to the magnet and has its sharp end pointing dorsally. Another foreign body and gas shadows are seen cranial to the reticulum. The lung and diaphragm cannot be differentiated because of soft tissue density. (Reproduced from Braun *et al.*, 2007b).

Figure 15 : Ultrasonogram of pleural effusion in a cow with traumatic pericarditis obtained via the seventh intercostal space on the left side using a 5.0 MHz linear transducer. 1 Thoracic wall, 2 Costal pleura, 3 Pleural effusion, 4 Pulmonary pleura, 5 Lung, Ds Dorsal, Vt Ventral. (Reproduced from Braun *et al.*, 2008).

Figure 16 : Ultrasonogram of pericardial effusion with strands of fibrin on the epicardium in a cow with traumatic pericarditis. A 5.0 MHz convex transducer was placed in the fifth intercostal space on

the left side to obtain the image. 1 Thoracic wall, 2 Pleural effusion, 3 Consolidated lung with fluid bronchograms, 4 Thickened pericardium, 5 Hypoechogenic pericardial effusion, 6 Fibrin strands, 7 Epicardium, 8 Heart, Ds Dorsal, Vt Ventral. (Reproduced from Braun *et al.*, 2008).

Figure 17 : Ultrasonogram of a pericardial abscess in a cow with traumatic pericarditis obtained from the fifth intercostal space on the left side using a 5.0 MHz convex transducer. 1 Thoracic wall, 2 Pleural effusion, 3 Thickened pericardium, 4 Hyperechoic fluid in the pericardial sac (abscess), 5 Thickened epicardium with fibrin deposits, Ds Dorsal, Vt Ventral. (Reproduced from Braun *et al.*, 2008).

Figure 18 : The heart and pericardial sac of a cow with traumatic pericarditis. The pericardial sac has been opened and the heart is covered with fibrin.

414 Table 1: Cardiovascular findings in 28 cattle with traumatic pericarditis (Reproduced from Braun et
415 al. 2007a)
416

Variable (mean [sd])	Finding	Number of cattle
Heart rate (104 [16] bpm)	Normal (72-80)	2
	Slightly increased (81-90)	6
	Moderately increased (91-99)	1
	Greatly increased (100-130)	19
Intensity of heart sounds	Normal	8
	Muffled	20
Audibility of heart sounds	Same on both sides	21
	Louder on left side	5
	Louder on right side	1
	No sounds on right side	1
Heart rhythm	Normal	26
	Tachyarrhythmia	1
	Could not be assessed	1
Pericardial sounds	None	18
	Splashing sounds	7
	Rubbing sounds	2
	Squeaking sounds	1
Heart beat	Palpable	26
	Not palpable	2
Jugular veins	Normal	3
	Bilateral distension	24
	Jugular pulse	1
Oedema	Throat region	15
	Brisket	14
	Umbilicus	6
	Cranial to udder	4
Scleral vessels	Normal	6
	Injected	22

417 Table 2 : Results of radiography of the reticulum in 28 cattle with traumatic pericarditis (Reproduced
418 from Braun et al. (2007b)
419

Classification	Description	Number of cattle	Additional findings
Perforating foreign body	Foreign body partially (n=5) or completely outside of the reticulum (n=9); gas shadows (n=8), gas-fluid interface (n=1)	14	- 8 cattle: Gas shadows - 6 cattle: Reticular and diaphragmatic contour unclear - 1 cow: Gas-fluid interface
Penetrating foreign body	Foreign body has no contact with ventral aspect of reticulum (n=3) or is at an angle of >30º to the ventral aspect of the reticulum (n=1)	4	- All 4 cattle: Reticular and diaphragmatic contour unclear - 2 cattle: Foreign body not attached to magnet - 2 cattle with several foreign bodies
Non-penetrating foreign body	Foreign body on ventral aspect of reticulum (n=1) or attached to a magnet (n=2)	3	- 3 cattle: Reticular and diaphragmatic contour unclear - 1 cow: Long gas shadow cranial to reticulum
No foreign body	No foreign body (n=1), or magnet without attached foreign body (n=6)	7	- 2 cattle: No additional findings - 5 cattle: Reticular and diaphragmatic contour unclear; gas shadows in 2

420 Table 3: Postmortem findings in 28 cattle with traumatic pericarditis (Reproduced from Braun et al.
421 (2007a)
422

	Number of cattle	Definition
Fibrinous pericarditis	10	Visceral and parietal pericardial surfaces covered with variable amounts of yellow fibrinous deposits
Suppurative pericarditis	10	Purulent exudate, pericardial surfaces are markedly thickened by fibrous connective tissue
Constrictive pericarditis	5	Extensive fibrous proliferation and possible formation of fibrous adhesions
Suppurative pericarditis with abscessation	3	Encapsulation of purulent exudates

423 Table 4: Location of 20 foreign bodies found at necropsy in 20 cattle with traumatic pericarditis
424 (Reproduced from Braun et al. (2007a)
425

Organ	Location	Number of cattle	Remarks
Reticulum	Attached to magnet	7	- 5 cattle: tract through reticulum, diaphragm and pericardium visible - 1 cow: tract through reticulum and craniodorsal blind sac of rumen visible - 1 cow: no tract seen
	Free in reticulum	1	Tract through reticulum, diaphragm and pericardium visible
	Lodged in diaphragm	2	Foreign body in reticulum has perforated wall of reticulum and is lodged in the diaphragm
	Lodged in pericardium	1	Foreign body in reticulum has perforated wall of reticulum and diaphragm and is lodged in pericardium
Heart	Perforating pericardium and penetrating heart	5	
Reticulum/ Diaphragm/ Heart	Embedded in fibrous adhesions	3	Foreign body lodged in diffuse adhesions between reticulum, diaphragm and pericardium
Lungs	Right lung lobe	1	Foreign body has penetrated right lung lobe, tract through reticulum, diaphragm and pericardium visible